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ORIGINAL PAPER

Regeneration status of a sub-tropical *Anogeissus latifolia* forest in Garhwal Himalaya, India

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Abstract: The present study deals with the regeneration status of a sub-tropical forest located between 950–1100 m above sea level in Garhwal Himalaya. The vegetation was quantitatively analyzed on four different aspects i.e., east, west, north and south. Results of the study indicated that across the aspects, *Anogeissus latifolia* was dominant in tree, sapling and seedling layers in all the aspects, except north aspect where *Pinus roxburghii* and *Terminalia tomentosa* were dominant in tree and seedling layers, respectively. The highest tree layer density (380 plant·ha^{-1}) was recorded on south aspect and lowest (260 plant·ha^{-1}) on west aspect. In shrub layer, highest density was on east aspect (1790 plant·ha^{-1}) and lowest on west aspect (970 plant·ha^{-1}). Tree and shrub layer diversity ranged between 0.846 to 1.710 and 1.943 to 2.847, respectively. The relative lopping intensity (%) was higher in *Anogeissus latifolia* (45%-57% as compared to 4%–33% in other species) which is the most important tree species on all aspects, except north aspect. The present study also reveals that if the current rate of exploitation continues, the species like *Anogeissus latifolia* may be replaced by other species and drastic changes may occur in species composition and regeneration of the forest. The anthropogenic pressure, aspect and soil nutrients have caused changes in regeneration status and species composition of forests.

Keywords: *Anogeissus latifolia*; Garhwal Himalaya; tropical; regeneration

Introduction

Garhwal is an integral part of western Himalaya, India (29° 45′–50°0′ N, 78°32′–78°45′E). It is covered with a variety of forest types varying with altitudes. Within one altitude, the co-factors like topography, aspect and inclination of slope and soil type affect the forest composition (Shank and Noorie 1950). With the change in environmental conditions, the vegetation cover reflects several changes in its structure, density and composition (Gaur 1982). The most important structural property of a community is a definite quantitative relationship between abundant and rare species. The studies on floristic composition and phytosociological attributes are useful for comparing one community with the other (Singh 1976).

Regeneration status of trees can be predicted by the age structure of their populations (Marks 1974; Saxena and Singh 1984; Khan et al. 1987). The growth status of sufficient number of seedlings, saplings and young trees indicates a successful regeneration of tree population (Saxena and Singh 1984). Regeneration of species is greatly influenced by the interaction of different biotic and abiotic factors of the environment (Aksamit and Iring 1984). These factors may affect the recruitment, survival and growth of tree regeneration.

In the Himalayan region, the chronic forms of forest disturbances are found in which people remove only a small fraction of forest biomass. The problem with the chronic form of forest disturbance is that plants or ecosystems often do not get time to recover adequately because the human onslaught never stops (Singh 1998). This does not only affect the ecosystem but also arrest the succession of the communities.

The present study was conducted to understand the impact of anthropogenic pressure in term of livestock grazing /browsing, lopping of trees for firewood and fodder, felling of trees, litter removal etc. on regeneration status and community composition of a sub-tropical forest in Garhwal Himalaya.

Materials and methods

Location and climate

Geographically the Garhwal Himalaya is located between 29°31'9"–31° 26'5"N and 70°35'5"–80°6'E and exhibited sub-montane to alpine climates with distinct characteristics of the specific vegetation types. The present study was conducted in

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district Tehri Garhwal of a sub-tropical region (latitude 30°29'N and longitude 78°24'E) with an elevations ranging from 950–1100 m a.m.s.l., which is 15 km north of Srinagar city of Garhwal Himalaya. A total of four forest sites, differing in aspect, were studied to examine the regeneration pattern and community composition (Table 1). The sites experience a monotonic climate and can be divisible into three different seasons, viz., rainy (mid June–September), winter (October–February) and summer (March–mid June).

Table 1. Site characteristics of study area

Forest (average altitude, Above mean sea level)	Aspect	Anthropogenic pressure	Soil texture (%)			Organic carbon (%)	Phosphorus ($kg \cdot ha^{-1}$)	Potassium ($kg \cdot ha^{-1}$)
			sand	silt	clay			
A. latifolia forest (1100 m)	East	Low	8.9	17.0	74.1	0.48	10.16	162.03
A. latifolia forest (1000 m)	West	High	5.9	11.9	82.2	0.52	10.36	172.48
P. roxburghii forest (1100 m)	North	Moderate	7.8	12.7	79.5	0.47	9.67	141.87
A. latifolia forest (950 m)	South	Low	8.5	11.9	79.6	0.68	10.56	151.57

Vegetation analysis

The phytosociological analysis of tree, sapling, seedling and shrub layers was done by randomly 10 quadrats of 10m×10m in size in each site. The size and number of samples were determined following Saxena and Singh (1982). In each site, the number of lopped and unlopped trees of each species was noted down separately in each quadrate to calculate lopping intensity (%) of each species and relative values were calculated for each site. The vegetation data were quantitatively analyzed for abundance, density and frequency (Curtis and McIntosh 1950). The importance value index (IVI) for all the layers was determined as the sum of the relative frequency, relative density and relative dominance (Curtis 1959). Trees were considered as individuals >30 cm c.b.h. (circumference at breast height, 1.37m), saplings of 10–30 cm c.b.h. and seedlings of <10 cm c.b.h. following Saxena et al. (1984). The distribution pattern (%) was calculated following Whitford (1949). The diversity index (H) was calculated following Shannon and Wiener (1963) method as $H=-\sum(n_i/n)\log_2(n_i/n)$. The concentration of dominance (CD) was determined by Simpson's index as $(CD) = \sum (n_i/n)^2$ (Simpson 1949). The H and CD were calculated on the basis of density values. Dominance-diversity curves were plotted between IVI and species sequence.

Results and discussion

Soil characteristics

Soil was dominated by clay particles in all the four aspects (74.1% in east aspect and 82.2% in west aspect; Table 1). Proportion of sand and silt ranged from 5.9 to 8.9 and 11.9 to 17.0, respectively. Soil pH was acidic in all the four aspects (pH 6.33 to 6.43). The soil organic carbon (0.68 %) and phosphorus (10.56 $kg \cdot ha^{-1}$) were highest in south aspect while potassium was highest in west aspect (172.48 $kg \cdot ha^{-1}$), (Table 1).

Vegetation analysis

In east aspect, tree layer was dominated by *A. latifolia* (IVI, 171). The density and total basal cover of individual species ranged between 20 (*Aegle marmelos*, *Emblica officinalis*) to 230 $plant \cdot ha^{-1}$ (*A. latifolia*) and < 1 (*E. officinalis*) to 476 $cm^2 \cdot ha^{-1}$, respectively. The total density (Fig. 1), basal cover and species richness was 370 $plant \cdot ha^{-1}$, 779 $cm^2 \cdot ha^{-1}$ and 5, respectively. Similarly, sapling and seedling layers were dominated by *A. latifolia*. Sapling and seedling density ranged between 20–240 and 40–200 $plant \cdot ha^{-1}$, respectively (Table 2). In shrub layer, *Indigofera gerardiana* (IVI-43) was dominant with highest density and basal cover. Shrub layer species richness was 9 (Fig. 1).

In west aspect, *A. latifolia* was dominant species with highest IVI (114) and basal cover (138 $cm^2 \cdot ha^{-1}$). The total density and basal cover were 260 $plant \cdot ha^{-1}$ and 506 $cm^2 \cdot ha^{-1}$, respectively. Sapling and seedling layers were dominated by *A. latifolia*. In shrub layer, *Carrisa spinarum* was dominant species (IVI, 88).

Pinus roxburghii was dominant tree species in north aspect with highest IVI (225). The total basal cover was 1073 $cm^2 \cdot ha^{-1}$, about 90% of the total basal cover was contributed by *P. roxburghii* in this aspect. Sapling and seedling layers were dominated by *A. latifolia* (Table 2). In shrub layer, *C. spinarum* was dominant species (IVI, 71).

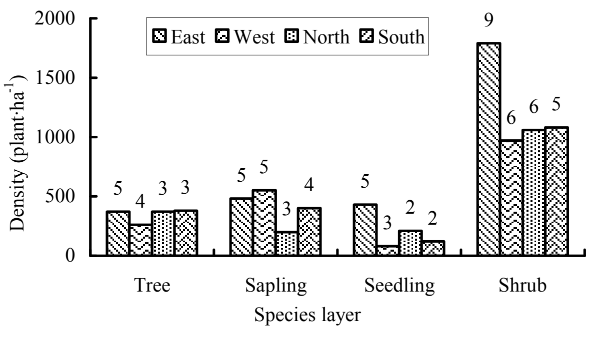

Fig. 1 Total density (bars) and species richness (numbers in bars) for trees, saplings, seedlings and shrubs in different aspects

In south aspect, *A. latifolia* was dominant species (IVI, 223). Other two species were *Lannea coromendalica* (IVI, 56) and *T. tomentosa* (IVI, 21). The total basal cover was 1003 $cm^2 \cdot ha^{-1}$. Sapling and seedling layers were dominated by *A. latifolia* (Table 2). In shrub layer, *Rhus parviflora* was dominant species (IVI, 82).

Across the four aspects, the highest density of tree layer (380

plant·ha^{-1}) was in south aspect and the lowest (260 plant·ha^{-1}) in west aspect (Fig. 1). The total basal cover (TBC) for tree layer ranged between 1 073.1 cm^2·ha^{-1} (north aspect) and 505.7cm^2·ha^{-1} (west aspect). These values were lower than the values reported by different workers for density (350 to 2 080 trees·ha^{-1}) and TBC (1 561 to 5 931 cm^2·ha^{-1}) for temperate forest of Central Himalaya (Saxena and Singh 1982). This may be due to selective felling of tree species by the local villagers for various purposes (fodder, fuel, agricultural implements, etc). Khera et al. (2001) have also reported lower total basal cover values (450 to 1 680 cm^2·ha^{-1}) for disturbed oak forest of Central Himalaya.

In shrub layer, the highest density value (1 790 plant·ha^{-1}) was in east aspect and lowest (970 plant·ha^{-1}) in west aspects (Fig. 1). The total maximum TBC for shrub layer was 4.4 cm^2·ha^{-1} in east aspect, and the minimum (1.8 cm^2·ha^{-1}) in north aspect. Agnihotri et al. (2006) indicated that aspect and physiographic positions, particularly on hills are expected to influence vegetation cover. This is because the south and east facing slopes have early sun shine of the day, while north and west aspects receive sun during the later parts of the day. Therefore, south aspect had total highest density of trees and east aspect could be favorable for the better growth of shrubs among the aspects as indicated total highest density (1790 plant·ha^{-1}). The shrub layer density and TBC values of the present study were lower than the range values reported for sub-tropical region of Garhwal Himalaya (2 760 to 2 999 plant·ha^{-1} for density and 65 to 135 cm^2·ha^{-1} for TBC), (Kumar et al. 2004). The lower values seems to be related to the variety of factors viz., grazing/browsing and trampling by livestock, burning of ground litter during summer to increases productivity of ground vegetation, collection of firewood, etc.

Table 2. Density (plant·ha^{-1}), total basal cover (cm^2·ha^{-1}) and IVI of saplings and seedlings in different aspects

Species	East			West			North			South		
	Density	TBC	IVI	Density	TBC	IVI	Density	TBC	IVI	Density	TBC	IVI
Sapling												
Anogeissus latifolia	240	66	143.56	320	71	153.57	90	27	129.56	320	55	199.93
Aegle marmelos	50	15	35.10	-	-	-	-	-	-	-	-	
Ougeinia oojenensis	110	24	58.92	-	-	-	-	-	-	-	-	-
Lannea coromandelica	20	14	18.86	120	29	64.79	-	-	-	30	14	40.76
Emblica officinalis	60	24	43.86	-	-	-	-	-	-	-	-	
Acacia catechu	-	-	-	40	11	28.66	-	-	-	40	12	45.87
Pinus roxburghii	-	-	-	40	23	36.25	70	40	119.99	-	-	-
Bauhinia veriegata	-	-	-	30	3.0	16.71	-	-	-	-	-	-
Terminalia tomentosa	-	-	-	-		-	40	10.6	50.44	10	5.0	13.43
Seedling												
Anogeissus latifolia	200	2	141.81	50	0.6	154.32	100	2.0	132.09	100	3.0	244.20
Aegle marmelos	40	0.3	29.03	20	0.2	86.82	-	-	-	-	-	-
Ougeinia oojenensis	90	0.4	49.09		-	-	-	-	-	-	-	-
Lannea coromandelica	50	1.0	44.00	-	-	-	-	-	-	20	0.3	55.80
Emblica officinalis	50	0.2	36.06	-	-	-	-	-	-	-	-	-
Bauhinia veriegata	-	-	-	10	0.3	58.86	-	-	-	-	-	-
Terminalia tomentosa	-	-	-	-	-	-	110	2.0	167.91	-	-	-

In sapling layer, *Anogeissus latifolia* was dominant in all the aspects with highest values of IVI, density and TBC. The least dominant species were *Lannea coromandelica* (IVI=18.86), *Bauhinia variegata* (IVI=16.71) and *Terminalia tomemtosa* (IVI=13.43) in east, west and south aspects respectively. Similarly in the seedling layer, *A. latifolia* was recorded to be dominant in all the aspects. The maximum and minimum values of IVI of *A. latifolia* among the aspects were 244.20 (south) and 132.09 (north) (Table 2), respectively.

Across the aspects, highest total density (430 plant·ha^{-1}) for seedling and highest total basal cover (143 cm^2·ha^{-1}) for sapling layers were recorded in east aspect. The earlier sunshine and low anthropogenic pressure in east aspect might be favourble for the growth of regeneration. Boring et al. (1981) have also emphasized the positive role of mild disturbances in improving the regeneration of trees. The species reported in the study area are frequently used by the local villagers for their basic demand (Table 3).

Population structure of a species in a forest can convey partly its regeneration behaviors, in relation to the reproductive strategy. Importance is given to the number of saplings under adult tree for predicting future composition of a forest community. The long history of human interaction with plant, animals and environment in the mountain region has a significant impact upon the biological diversity at different levels. The topography, soil, climate and geographical location influenced the vegetation diversity of forest. The greater diversity in the floristic pattern due to altitudinal variation coupled with rainfall has been well documented (Bisht and Lodhiyal 2005). In recent, years the Central Himalayan forest ecosystems have witnessed the great natural as well as biotic disturbances. These disturbances do not provide time for the ecosystem recovery and arrest the regeneration of the forest species (Singh 1998).

The lower population of tree seedlings (80 plant·ha^{-1}) in west aspect and especially of *A. latifolia* (50 plant·ha^{-1} as compared to 100-200 plant·ha^{-1} in other aspects) may be due to heavy anthropogenic pressure on the overstory species for fuel, fodder and other basic requirements of the villagers which affect the seed production of trees.

Table 3. Tree species in different aspects and ecosystem service to local people

Species	Vernacular name	Family	Ecosystem services to local people
Anogeissus latifolia Wall ex.D.Don	Dhau	Combretaceae	Fodder, fuel, timber, gum, agricultural implements
Terminalia tomentosa (Roxb.) Wight &Arn.	Asin	Combretaceae	Fodder, fruit for local medicine
Emblica officinalis Gaertne	Anwala	Euphorbiaceae	Fruits are used for prickle, local medicine
Acacia catechu (L.f.) Willd.	Khair	Fabaceae	Fuel, fodder for goat in forest
Ougeinia oojeinensis Hochr.	Sandan	Fabaceae	Wooden utensils/fodder/flower for vegetable
Aegle marmelos (L.) Corrêa	Bel	Rutaceae	Medicine
Lannea coromandelica (Houttuyn) Merrill	Kalmina	Anacardiaceae	Agricultural implements, firewood
Pinus roxburghii Sargent	Chir-pine	Pinaceae	Fuel wood

Distribution pattern (%)

The distribution pattern of the species in the different layers and aspects has been given in Fig. 2a-d. Among the aspects, the most tree species were distributed randomly and few species were distributed regularly in all aspects except west (Fig 2a). The contagious distribution for tree layer was found only in west and north aspects. In sapling layer, majority of species were distributed contagiously, few species were random in distribution and no species was found in regular distribution in all aspects (Fig. 2b) except east aspect. In seedling layer, the contagious distribution of species was dominant in all aspects except in south aspect where species distribution pattern (Fig. 2c) was random (100%). Similarly for shrubs, the contagious distribution was most common, (Fig. 2d).

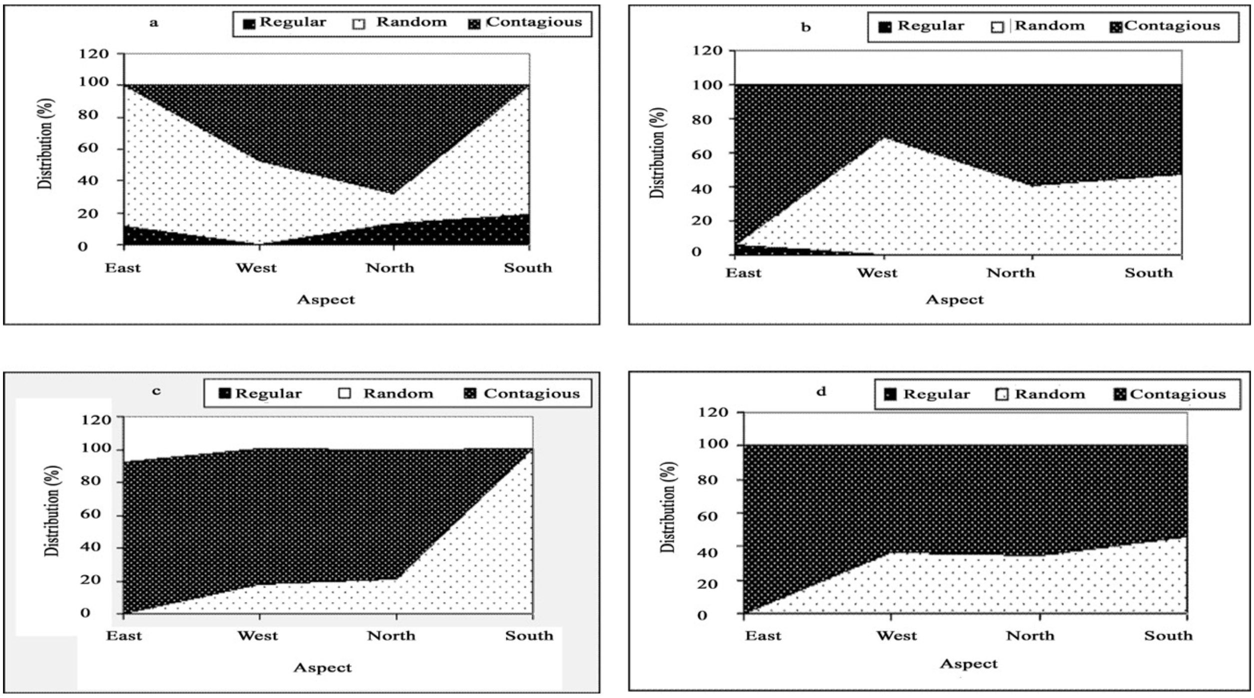

Fig. 2 Distribution pattern of trees (a), saplings (b), seedlings (c) and shrubs (d) in different aspects

Regular and random distribution pattern of species reflect the higher biotic pressure in terms of grazing and lopping in natural forest stands. Odum (1971) stated that clumped (contagious) distribution is the commonest pattern in nature, and random distribution is found only in very uniform environment and the regular distribution occurs where severe competition between the individuals exists (Panchal and Pandey 2004). Contagious distribution may be related to seed dispersal mechanism of the species and gap formation (Barik 1996; Kersaw 1973; Singh and Yadav 1974; Greig Smith 1957). Mehta et al. (1997) also reported random and contagious distribution pattern of species in various forests of the Garhwal Himalaya.

Species diversity (H) and concentration of dominance of concentration (CD)

The CD and H values of different layers of forest on different aspects are indicated in Fig. 3a-d. The ranged values of diversity for trees (0.846 in south-aspect to 1.710 in west-aspect) and shrubs (1.943 in west-aspect to 2.847 in east-aspect) of present study were comparable with the reported values for temperate (Adhikari et al. 1991; Bhandari et al. 2000) and sub-tropical (Kumar et al. 2004) forests. Similarly, the range values of CD for trees (0.326 to 0.693) and shrubs (0.185 to 0.719) are within the

range (0.10–0.99) reported by various works (Risser and Rice 1971; Knight 1975). The H and CD of saplings and seedlings in various aspects (east, west, north and south) are given in Fig. 3. The highest diversity among the aspects for sapling layer was in east aspect (1.520), whereas, the lowest in south aspect (1.10). Value of diversity in west and north aspects was 1.309 and 1.146, respectively. The maximum and minimum values of diversity in seedling layer were 1.435 and 0.496 in west and north aspects, respectively. The highest (0.655) and lowest (0.331) values of CD for sapling layer were recorded in south and east aspects, respectively. The range values of CD for seedling layer were 0.294 (east-aspect) to 0.722 (south-aspect).

Dominance diversity (d-d) curve

Dominance-diversity curves were developed for trees, saplings, seedlings and shrubs (Fig. 4a-d). The dominance-diversity (d-d) curve approaches a geometric series for the trees. Mostly the curve follows the geometric series in conformity with niche pre-emption hypothesis (Motonura 1934). The geometric form is often shown by vascular plants having lower density (Whittaker 1975).

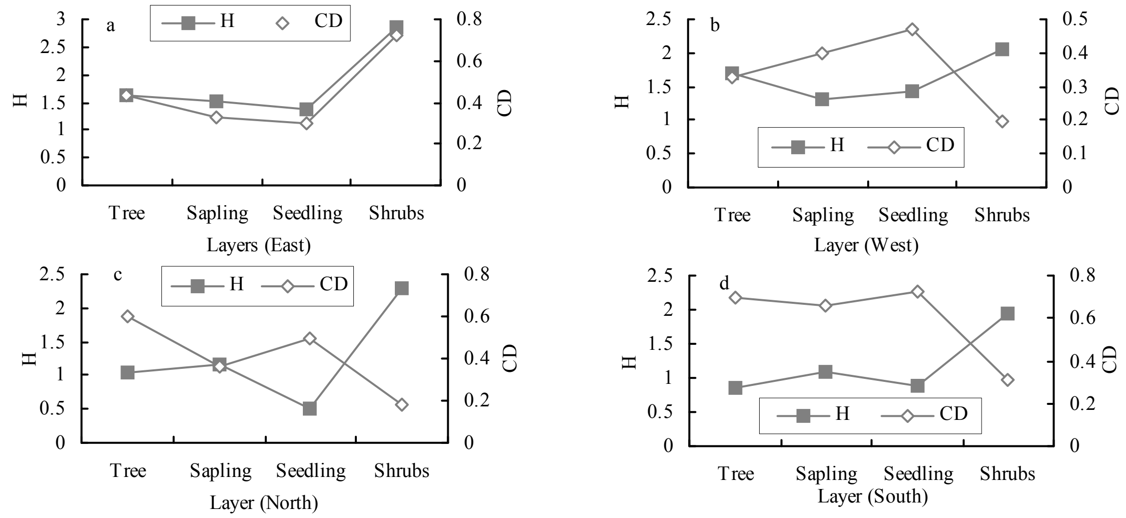

Fig. 3 Diversity (H) and Concentration of dominance (CD) of trees (a), saplings (b), seedlings (c) and shrubs (d) in different aspects

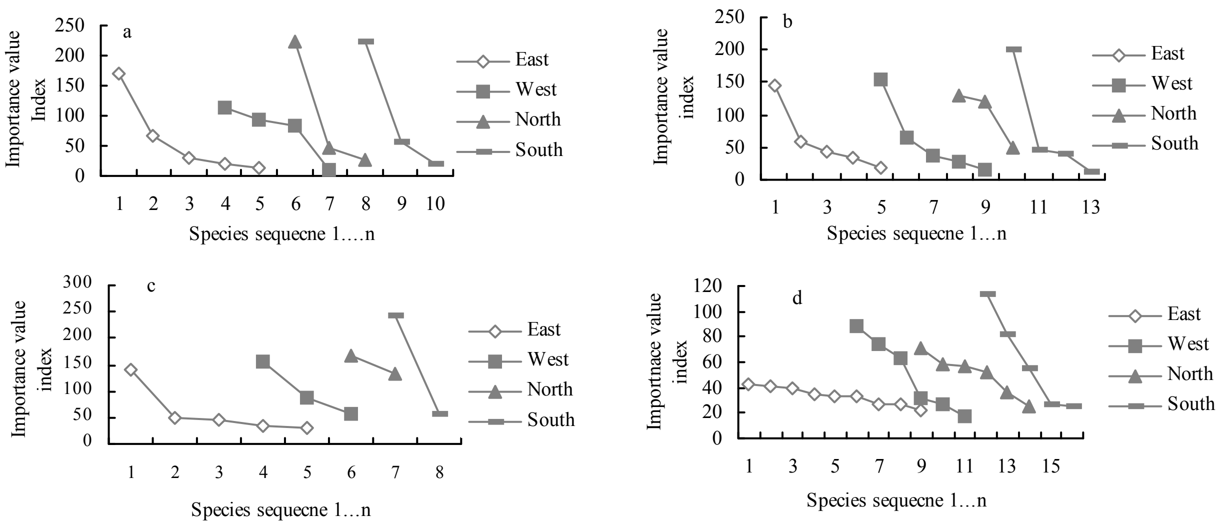

Fig. 4 Dominance-diversity curves for trees (a), saplings (b), seedlings (c) and shrubs (d) in different aspects

Anthropogenic pressure

The anthropogenic pressure in terms of uncontrolled or selected felling, lopping of trees for firewood and fodder, livestock grazing/browsing, litter removal, etc. was low in east and south aspects, moderate in north aspect and high in west aspect (Table 1). The density of seedlings was low in west aspect (80 plant·ha^{-1}), compared to other aspects (120–430 plant·ha^{-1}). Across the aspects, *A. latifolia* showed dominance in tree, sapling and seedling layers in all the aspects, except north aspect where *Pinus roxburghii* and *Terminalia tomentosa* were the dominated tree and seedling layers, respectively. The relative lopping intensity (%)

values for tree species in different sites showed that anthropogenic pressure in terms of lopping of trees was very high in all the sites. All the species were lopped by the villagers, however, the intensity of lopping on different species varies across the sites (Table 4). The relative lopping intensity (%) was higher in *A. latifolia* (45%−57%) as compared to 4%−33% in other species) which is the most important tree species on all the aspects, except north aspect where *Pinus roxburghii* showed his dominance. The results of present study indicate that *A. latifolia* which is very important in providing various ecosystem services to local people, may be replaced by some other species and drastic changes may occur in species composition and regeneration of the forest.

Table 4. Importance value index (IVI) and relative lopping intensity (RLI, %) of tree species in different aspects

Species	East		West		North		South	
	IVI	RLI	IVI	RLI	IVI	RLI	IVI	RLI
Anogeissus latifolia	171	52	114	57	48	49	223	45
Aegle marmelos	18	4	-	-	-	-	-	-
Emblica officinalis	15	4	-	-	-	-	-	-
Ougeinia oojeinensis	29	11	-	-	-	-	-	-
Lannea coromandelica	67	29	92	20	-	-	56	33
Pinus roxburghii	-	-	83	10	225	23	-	-
Acacia catechu	-	-	-	-	-	-	-	-
Terminalia tomentosa	-	-	11	13	27	28	21	22

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